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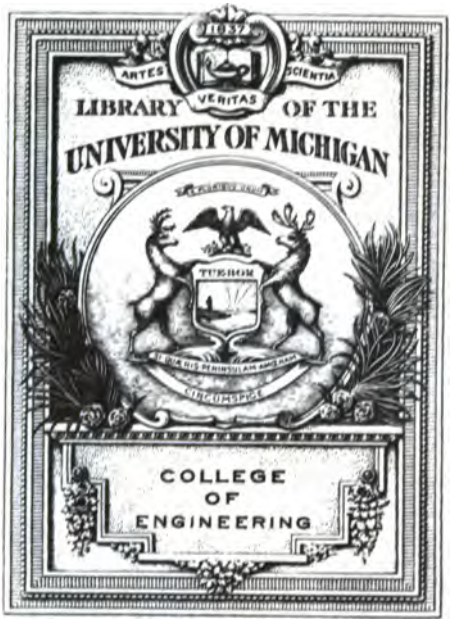

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UNIV. OF MICH. ENG'G. SHOPS

Suction Gas

BY

OSWALD H. HAENSSGEN.

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THE GAS ENGINE PUBLISHING CO.,
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PREFACE.

Owing to the economies necessarily practiced in Europe, where nature has not furnished a supply of liquid or gaseous fuel for internal-combustion engines, the production of industrial gas from coal or other fuels has advanced considerably more than in America. Consequently, it is not surprising that the suction gas producer has been developed and improved in Europe, rather than in America, where nature has been more generous in her supply of coal and other fuels which were accordingly low enough in cost to prevent the necessity of practicing the greatest possible amount of economy in the generation of power.

Germany has been foremost in the development of the alcohol motor, because of the necessity of providing a motor to meet the fuel at hand. Likewise, she has had occasion to develop a system of

producing gas from coal, etc., for use in gas engines.

America has become greatly interested in this system. Several makes of European suction gas producers have been brought over, and others have been designed in accordance with results of American investigations. Other manufacturers have endeavored to investigate the subject, and users of power have become interested in this new type of producer and its economies. And yet, so far there has been no reliable literature on the subject. This work has been published with a view of supplying the demand for information on this subject. The design, operation, cost of running, development and possible utility of this type of gas producer are all covered.

Suction Gas.

During the last few years a novel type of gas producer has found pretty wide-spread application in the industrial countries of Europe. It is a close relative of the well-known Dowson gas generator. As this latter apparatus produces at a very low expense, a fuel gas excellently suited to the requirements of the gas engine, it has, no doubt, contributed much to the prominent position which this prime mover holds at present, and has rendered the large-sized motor capable of successful competition with the steam engine. But in spite of all its good properties the Dowson gas producer appears somewhat too complicated and too bulky for small-sized power plants. The unavoidable gas-holder takes up more space than all the other parts combined, and the boiler necessary for the production of the steam,

entering into the generating process, is another undesirable appendage. This boiler receives special attention from the cautious European authorities who, faithfully supported by the various insurance companies, see fit to place upon it all the legal restrictions that apply to steam plants in general.

From a technical standpoint the boiler also shows many unfavorable points. It requires a considerable amount of attendance and much labor for repairs and cleaning. Time is lost in starting. It also consumes an appreciable quantity of fuel for which no returns are obtained. This latter loss is estimated at 8% of the fuel consumption of the generator proper.

In the new type of gas-producer the troublesome boiler and the bulky gas-holder are entirely dispensed with. The combustible gas is produced directly and exclusively by the suction of the motor. The other elements of the gas plant are much simplified. An installation of this kind for 3 or 4 H. P., offers practically the same economy as a large Dowson gas

plant, and as hard coal or coke are used the running expenses are surprisingly low.

Though somewhat different in their exterior appearance, both kinds of producer plants consist of the same apparatuses, and the generating process and the product of the same are identical in both cases.

The operation may be explained in a few words: Air laden with water vapors is passed through a column of red-hot coals. The carbonic acid produced by the imperfect combustion of the coals is reduced to oxide of carbon, the water vapors decompose into hydrogen and carbonic acid and the latter is also for the greatest part changed into oxide of carbon. The gas, or rather the mixture of gases thus obtained, passes through cooling and purifying devices and then enters the engine.

The only marked difference in the two types of producers lies in the manner in which the air and the water are brought to the fuel. In the Dowson plant, the energy of the steam issuing from the boiler carries the air along into the generator proper. In the suction gas plant the depression caused by the suction stroke of

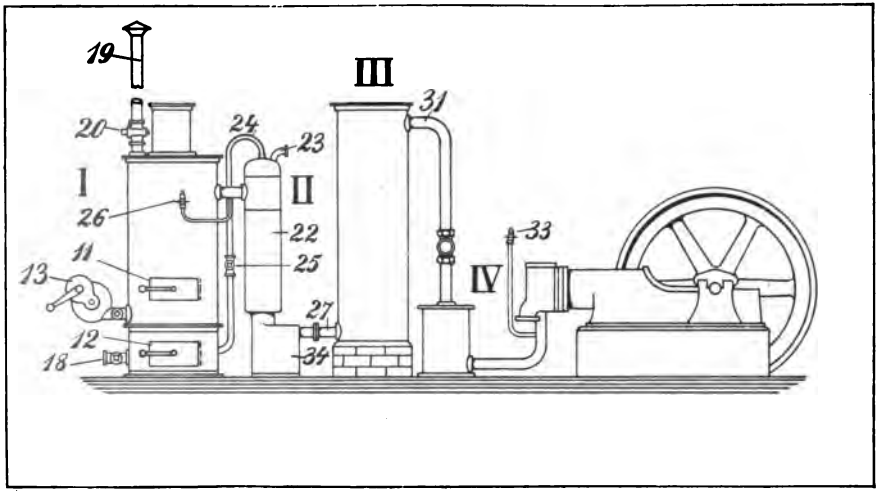


FIG. 1.

the motor extends through the pipes and various apparatuses and causes the air to enter below the grate of the generator, in order to establish atmospheric pressure therein. The air passes through water vessels and takes up sufficient steam for the generating process.

Fig. 1 shows the typical arrangement of a small suction gas plant, while Fig. 2 illustrates a more complete installation of great capacity. Like or similar parts are marked by like characters in both figures. The plant consists principally of the generator I, the steam producer or vaporizer II, the cooler and purifier III and the pressure equalizer IV. In Fig. 2, some additional devices for the more perfect purification of the gas are shown, which will be treated later.

Naturally, all of the apparatuses may be built in different ways, in fact every manufacturer has designs of his own for which he claims special advantages. But as the principle is alike in spite of the structural differences, a description of the parts with reference to the illustrations will suffice for the general information of

the reader. Nevertheless, the more important variations will be mentioned as occasion arises.

The Generator.

The generator I consists of a cylindrical shell (1) of sheet-iron (for small types sometimes cast iron is used) which is lined with fire-bricks (2) supported by suitable fittings (3, 4 and 5). By the shape of the lining the interior of the generator is divided in two distinct chambers, the fire space (6), in which combustion takes place, and the heating space (7), which serves as a receiver for the coal. Between these two spaces an annular chamber (8) is formed in which the flame may develop and the gas collect. A grate (9) at the bottom of the fire-space (6) supports the column of fuel. The fire-space as well as the ash-pit (10) are provided with doors (11 and 12) which may be closed hermetically by a lever or spindle.

Frequently a flat vessel is placed in the ash-pit and kept full of water, the evaporation of which cools the grate-bars.

A ventilator (13) is connected to the ash-pit and a cock or valve (14) serves to shut it off.

In order to facilitate the charging of the generator a funnel is fixed to the top plate. Many firms used the standard patterns of their Dowson gas producers and thus often enough the well-known curved funnel with its balanced valve at the bottom and the lever-operated cover at the mouth is seen on the suction gas generator also. Usually, however, the device is much simplified in accordance with the more favorable conditions. In many cases a short, wide barrel is cast onto the top plate and closed by a hinged cap. In one instance the funnel proper is hinged to the top plate and may be tilted out of the way if an inspection of the generator becomes necessary. The device recognizable in Fig. 2 is well adapted for continuous service and the generator may be charged without admitting air to its interior. Two or more barrels (15) cast in one piece are arranged about a central pivot (16) while a plate (17) covers the barrel which registers with the filling hole

of the generator. The barrels are filled with coal and are swung around in succession whereby their contents are dropped into the heating space.

An air valve (18) permits the entrance of air under the grate if it is desired to keep the generator burning during short stops of the engine. The products of combustion escape in this case through a flue (19) provided with a valve (20).

In the top plate of the generator, and in other suitable places of its walls, little openings are provided that permit the introduction of iron bars for the removal of slag clinging to the generator lining. These poke-holes are formed by tube-like castings of some 2 or 3 inches diameter, which must be rigidly fastened to the metal parts of the generator in order to avoid their being shaken loose by the rather rough operations of the poke bars, resulting in injuries to the fire bricks. As by the location of the poke-holes every part of the interior of the generator which can not be reached through the doors must be rendered accessible, their arrangement requires great care, and, as in many

other details also, only experiment can show the right way.

As the lining of the generator is of great importance for the safety and economy of the whole plant, a few remarks referring thereto may prove of value to those not familiar with the equipment of furnaces.

Good fire-bricks are produced by comparatively few works, as their quality depends not so much on the methods of manufacture but on the properties of the material used. The blocks necessary for the lining of the generator must be made according to exact drawings and must fit their respective places nicely with a clearance of about one-sixteenth of an inch. Consequently each series of blocks can only be used for one size of generator. The bricks are laid in a thin mortar of water and fire-clay which does not bind them but simply renders the joints gas proof. The lining does not fit the iron shell of the generator closely, and the clearances are filled loosely with ashes that reduce losses of heat by radiation and also permit the expansion of the parts.

As fire bricks are very brittle and offer

only little resistance to pressure, blows, or sudden changes of temperature, great care must be exercised not to damage them when slag or other refuse is being removed. If their surface is broken during cleaning operations, or by the action of the heat, they soon crumble to pieces and cause laborious and costly repairs.

The blocks surrounding the fire space (6), also those covering the gas chamber (8), must be of highest fire-proof quality while the rest may be of lower grade.

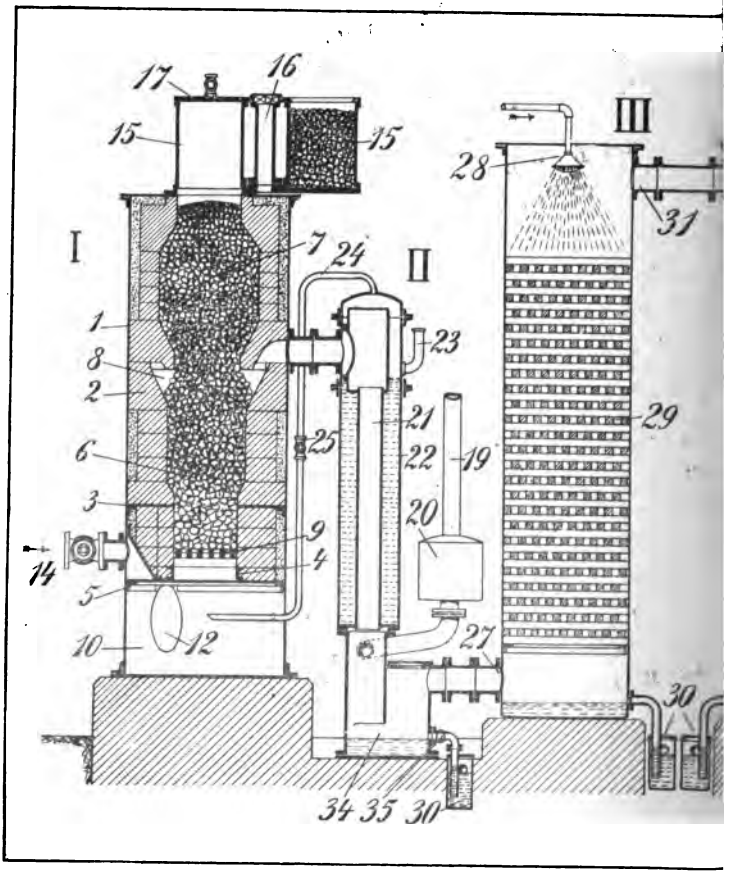
The grate of the generator is made in many different ways, though for small types the plain cast iron grate is preferred. Large grates are composed of single grate bars of a special hard iron. Often the grate, as a whole, or part of it, is made movable and may be turned about in a horizontal direction or tilted in order to remove ashes and refuse.

One prominent firm holds a patent on a cone-shaped grate, the apex of which projects into the fire-space while its base rests on the bottom of the ash-pit. Concentric rings around the cone form the grate-bars. The whole device may be re-

volved by bevel-gears whereby the ashes are caused to slide down.

A grate construction of striking originality has been devised by a French engineer. A hollow cast-iron cylinder passes the shell of the ash-pit and is revolubly supported in two journals. The central part of the cylinder just below the fire-space is closely studded with short square projections or teeth that carry the fuel and form a substitute for the grate-bars. On the bottom of the ash-pit a comb-like contrivance is fixed, the prongs of which enter the clearances between the teeth. By turning the cylinder occasionally the teeth are successively brought in contact with the fire whereby the wear is distributed equally over a large surface. Water is constantly passed through the hollow of the grate cylinder cooling it energetically and at the same time generating the steam necessary for the gasifying process.

Though this is one of the oldest grate constructions it offers so many advantages that it is of considerable interest at the present time. It was invented by Mr. Benier in 1898.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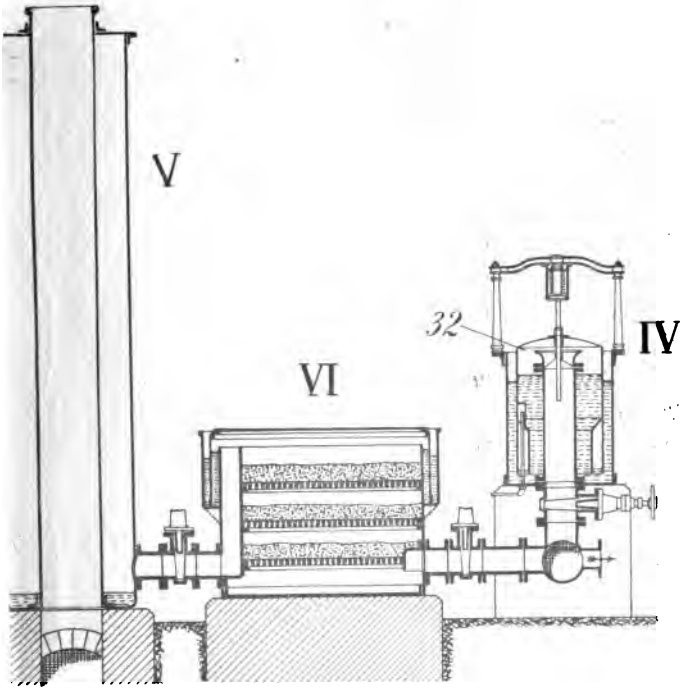

. 2.

As far as the dimensions of the generator are concerned no precise rules have been established yet. Its principal dimension, the area of the fire-space or the grate-surface, may be developed from the following contemplation. A generator is practically the same as a closed stove in which a certain amount of fuel must be consumed. The size of the grate surface depends on the height of the column of fuel, on the strength of the suction, that is the amount of air drawn through it, also on the rate at which the plant is being worked. Of course the capacity of a gas generator is greater than that of a common furnace that serves for heating purposes, as the coal is not to be burnt completely but rather gasified. A ship-boiler-furnace with forced draft burns easily 31 pounds of coal for each square foot of grate surface, a figure which in locomotive practice rises as high as 200 pounds per square foot. As each pound of coal develops about 64 cubic feet of gas, one square foot of grate area would supply at least $31 \times 64 = 1984$ cubic feet of gas. The average consumption of gas is 105 cubic

feet per actual H. P. hour. Consequently the above amount would suffice for 1984÷105=19 B. H. P. (nearly) and for each B. H. P. 1-19th or .053 of a square foot would be required. In fact this figure coincides pretty well with those calculated from approved plants that possess from .048 to .064 square feet of grate area for each H. P. if anthracite is used, while for coke about .085 square feet are provided. For more voluminous or poorer fuels more liberal dimensions should be chosen, especially as a little surplus of capacity will not do any harm, while a deficiency in this respect may prove troublesome. The height of the column of fuel may be made about 5 or 6 times as high as the diameter of the grate in order to reduce the frequency of recharging. The grate area should be so divided that about 30 percent of it is occupied by the bars while the remaining 70 percent constitutes air passages. The other measurements of the generator depend upon the general experience and individual judgment of the designer.

The Vaporizer.

The vaporizer II serves to produce the steam which is necessary for the generation of the gas. It is the substitute of the steam boiler in the Dowson gas plant. The special difference lies in the fact that the vaporizer requires no fire place of its own, as the heat of the generator or of the gases is applied instead. Among the great numbers of varieties three distinct types are recognizable.

In the first type the water vessel is placed in the upper part of the generator, surrounding the heating space, and drawing its heat from the latter. This is a very simple but not recommendable plan as the generator proper should be carefully protected from losses of heat.

In the second and more frequent type, which is illustrated in the accompanying figures, the hot gases immediately upon leaving the generator enter a system of tubes (21) surrounded by a shell (22) and partly immersed in water. While the gas is cooled the water is heated. The low-tension steam gathers at the top of the

vaporizor and is, together with the air entering at the nozzle (23), drawn through the pipe (24) into the ash-pit (10). A valve (25) in pipe (24) serves to regulate the passage of the steam.

The third type which at present is built only by the firm owning the patent right has no water reservoir at all. By the suction of the motor an adjustable amount of water is sprayed directly on the hot gas pipes, and vaporized immediately. The steam is then overheated by coming in contact with large heating surfaces before entering the generator. As the steam is dry it withdraws no heat from the fuel, its amount is exactly adjustable and depends on the power requirements of the motor, consequently the composition of the gas remains uniformly at the once regulated most favorable mark. The cooling effect in the vaporizer is excellent and only little heat must be withdrawn from the gas in the next apparatus. This type of vaporizer embodies the most favorable principles and is superior to the two preceding types.

The dimensions of the vaporizer de-

pend mostly upon the amount of water required, the maximum amount of which is .25 gallons per H. P. hour. As in steam boiler practice one square foot of heating surface may evaporate as much as 1.25 gallons, the above named quantity of water would call for about .2 square feet of heating surface.

In the vaporizers of the first and second type, water is constantly supplied and a constant level maintained by an overflow. The surplus generally flows into the water pan in the ash pit previously mentioned. Near the outlet of the generator a small pipe with a test cock (26) is branched off.

Next, the gas enters the cooling and cleaning devices which, in small plants, are generally combined in one single apparatus, as is shown in Fig. 1.

In some suitable part of the pipe leading from the generator to the cooler a valve must be provided in order to shut off the cooler if desired. In the illustrations this valve is not shown and another device is substituted. If the cock (35) is closed, the water in box (34) rises above its usual level and soon reaches the parti-

tion in the box. Thus the gas is shut off. Consequently the box (34) acts as a shut-off valve for the scrubber. The pipe (19), starting from the box, serves to lead away the products of combustion. In the vessel (20) a kind of safety valve is contained acting like a siphon.

The Cooler.

The cooler III, which, in conformance to the nomenclature of the illuminating gas industry, might also be called the scrubber, consists of a tall, cylindrical, upright, standing vessel constructed of sheet iron. The gas enters through the inlet (27) at the bottom of the cylinder and, rising slowly, it is impeded by a large number of wooden gates (29) laid crosswise. Water is constantly sprinkled on these gates by a spraying nozzle (28) at the top of the scrubber. The gas is frequently parted and reunited on its path upward and comes in close contact with the many wet and cold surfaces and loses much of its heat. Besides this, the particles of dust floating in the gas are moist-

ened, and they either cling to the surface or are carried down by the drops of water, which gather at the bottom of the cooler. The surplus is drained in the customary manner by a siphon (30). Frequently the scrubber is filled with pieces of coke supported by an iron grate. This filling is cheaper than the wooden one and is very effective on account of the large surface and porosity of the coke. Cleaning operations, however, are more troublesome in this case as the coke must be taken out and replaced by fresh material. An outlet (31) for the gas is provided at the top of the cooler.

The cubical contents of the cooler should suffice to receive about 1.2 cubic feet of gas for each actual H. P. If, however, the vaporizer has a considerable cooling efficiency this figure may be reduced in proportion. Generally the diameter of the scrubber is not made more than 4′ and its height does not surpass 12′ though of course these dimensions are only limited by manufacturing facilities and by the space available for the erection and the treatment of the plant. A scrubber of the

aforementioned maximum dimensions has a capacity of 150 cubic feet and should suffice for 150÷1.2=125 H. P.

If for large plants it becomes necessary to provide more cooler capacity it is customary to use two or more smaller coolers and connect them in series in such a manner that the gas enters each vessel at the bottom and leaves it at the top. In this case it would be a good plan to follow the example of the illuminating gas works and arrange a by-pass whereby it is possible, in an emergency, to cut out any one of the scrubbers without interfering with the proper operation of the others and of the whole plant.

Scrubbers for small plants are often made of cast iron. While an apparatus of this kind is quite a nice-looking piece of machinery it is generally much more expensive in material and workmanship than the wrought iron one. Often this method of constructing is responsible for a reduction in the size of the scrubber that is not at all compatible with its proper working.

When the gas has passed the cooling

and cleaning devices it should be practically free of dust, dry and of the average temperature of the atmosphere. If in large plants these results cannot be obtained by the scrubber alone, the gas must be conducted through some other apparatuses.

A good example of a more complete producer plant which is provided with an additional cooler or condenser and a special purifier, is the one illustrated in Fig. 2.

The Condenser.

The condenser V is a sheet-iron cylinder vertically traversed by one wide central tube or by a great number of narrower tubes. The gas enters at the top, the space left between the outward shell and the air tubes, travels down slowly and makes its exit at the bottom. In its path the gas comes in contact with the large air-cooled surfaces. The moisture which the gas has taken up on its passage through the scrubber condenses at the cold walls, the water collects at the bottom of the condenser and is drained automatically

in the usual manner by a siphon (30). The heat withdrawn from the gas is imparted to the metal of the tubes and a natural draught is induced which causes the cold air to rise and travel through the tubes.

The Purifier.

The purifier VI is an exact copy of the apparatus used in illuminating gas works, though its functions are entirely different. This apparatus does not exert any chemical influence upon the gas, but acts strictly as a mechanical filter. It consists principally of a large rectangular cast iron box of single plates, bolted together. Its upper rim is double, forming a U shaped continuous vessel for the reception of the vertical walls of the sheet iron cover. The rim is filled with water which makes a gas-proof joint. Within the box several wooden grates are arranged upon which layers of sawdust are spread. The gas works its way from the top of the purifier through the layers of sawdust, which retains the smallest particles of solid matter and leaves the box at the bottom in a perfectly clean condition.

In the various devices a considerable resistance is offered to the travel of the gas on account of the friction in the long and tortuous passages, also by the impact on the many surfaces. This resistance must be overcome at every suction stroke by the motor, and as the action of the latter, especially if it belongs to the four-cycle type, is rather jerky, the gas must be alternately accelerated and retarded. In order to render the motion of the gas more uniform, whereby the action of the apparatuses is considerably improved, a special equalizer or regulator has been devised which is placed close to the motor, and by which the influence of the suction stroke is extended to the intermediate line also.

The Regulator.

The regulator IV in its simplest and also *least* effective form is a plain vessel, the contents of which amount to about four or five charges of the motor cylinder. Its action is rather illusory and may, in theory at least, be explained as follows: The depression caused by the suction of the motor is naturally strongest near the

engine and decreases gradually in proportion to the distance from the motor. The pressure of the atmosphere tends to fill the partial vacuum and consequently the gas continues to flow towards the engine even after the inlet valve has been closed. Thus the equalizing vessel receives a fresh supply of gas of comparatively high pressure which is ready to enter the engine.

One manufacturer places a filtering contrivance in this vessel. The gas pipe terminates in the bottom of a hood of perforated sheet iron which is wound with ropes of asbestos or wood shavings. Before starting the engine this material is moistened with a small quantity of coal-oil. The dust floating in the gas sticks to the filtering mass, and the traces of dirt entering the motor are said to remain so soft that they may be wiped off the valves, etc., with a rag.

The regulator shown in Fig. 2 is a much more complicated device, which is only found in high-grade plants of large capacity. Its action is more energetic and precise than that of the plain gas pot, and

it is especially desirable if several motors must draw their fuel gas from *one* generator, and if the load of the engines varies frequently. The little spring-retained gas holder (32), which is partly immersed in water, descends under the influence of the suction, and the spring is expanded. At the end of the suction stroke the gas holder rises again to its upper position under the contraction of the spring, and draws in a fresh supply of gas. The tension of the spring, and consequently, the energy of the regulator, may be adjusted to meet the varying requirements of the engine.

This contrivance distributes the suction practically on all the strokes of the motor.

A short pipe connects the regulator with the motor. Near the inlet valve of the latter a thin pipe, carrying a test cock, (33) is branched off.

The Pipes.

As the pipes connecting the different apparatuses are generally very short, a rather rough calculation suffices to determine their area.

It will be proper to choose their size at least equal to the size of the gas-inlet of the motor, and, assuming the average speed of the gas in the pipes to be about 82 feet per second, their area may be calculated from the formula

$$a = \frac{V \times n}{60000} \text{ square inches,}$$

in which V denotes the volume of a cylinder charge, n is the number of r. p. m., and a is the area of the gas pipe.

The formula is derived as follows:

The amount of gas contained in one charge is somewhat less than one-half of the cylinder volume, and is here, for the sake of simplicity, taken as one-half exactly.

If D is the diameter and S the stroke of the piston, the cylinder volume

$$V = \frac{D^2 p \times S}{4}$$

$$(p = 3.1416)$$

and the volume of gas contained therein

$$v = \frac{D^2 p \times S}{4 \times 2} = \frac{V}{2}$$

the duration of one suction stroke equals one-half revolution,

$$t = \frac{60}{n \times 2} = \frac{30}{n} \text{ seconds,}$$

and the amount of gas which would pass the pipe if the suction were continued at the same rate for one second would be

$$\frac{1}{t} \times v = \frac{n \times V}{30 \times 2} = \frac{V\,n}{60} \text{ cubic inches.}$$

At the before mentioned speed of the gas, 82 feet per second, or 82 × 12 ins., the area of the pipe is found to be

$$a = \frac{Vn}{60 \times 82 \times 12} = \frac{Vn}{59040}$$

or, somewhat simplified,

$$a = \frac{Vn}{60000} \text{ square inches,}$$

and the diameter of the pipe is

$$d = \sqrt{\frac{Vn}{15000\,p}} \text{ square inches.}$$

The dust floating in the gas is liable to settle wherever a change in the direction of the current occurs, especially in the bends of the pipes. This is necessarily most often between the generator and the

scrubber. Consequently, the pipes must be cleaned often, and in their construction facilities for this purpose should be provided. If wrought iron pipe is used, the bends should be flanged as in Fig. 3, a, in order to be easily detachable. The adjoining straight pieces should in all cases be well supported. Sketch b shows the application of a wrought iron cross, which may be cleaned by unscrewing the plugs. Cast iron elbows should have a cleaning hole of sufficient size, as drawn in c. A cross piece d, however, is preferable, as both the vertical as well as the horizontal branch of the pipe are fully exposed by removing the flanged covers. Besides this, the cross pieces offer a space for the accumulation of the dust, and thus the flow of gas is not impeded.

A set of wire brushes, with long flexible handles, is required for the cleaning of the pipes. In laying out the course of the latter sufficient space for the cleaning operations must be allowed.

One firm places a dust separator of very simple design, and which is claimed to be very effective, between the generator and

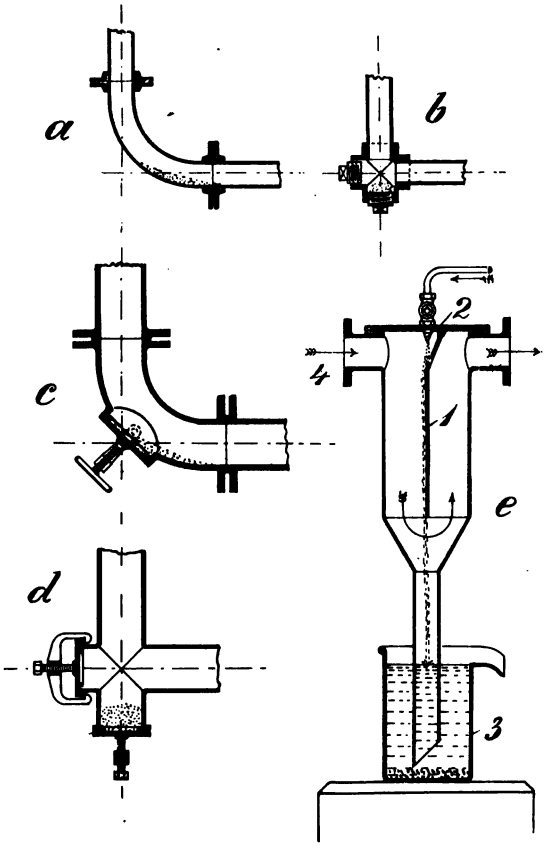

FIG. 3.

the scrubber in all their power plants above 30 H. P. It is shown in section in sketch e, Fig. 3. The inlet (4) is fixed directly to the outlet of the generator, and the gas travels in the direction of the arrows. It strikes the vertical partition (1), which is kept wet by a thin stream of water entering at the top through the nozzle (2). The dust sticks to the wet surface, and is carried down by the water into the siphon-like pot (3), whence the mud is removed occasionally.

In another make the dust separator is placed just below the gas inlet of the motor. A widened part of the gas pipe is provided with a long cover fastened by a single bolt. The cover carries a frame, which closely fits the interior of the gas pipe, and contains a great number of fine brass-wire sieves. By a single motion of the hand the cover may be undone and the sieves are exposed for cleaning.

In high-grade plants, especially in those of large capacity, the various apparatuses and some important places in the pipes are provided with gauges that per-

mit observation of the depression within. By these gauges the proper working of the plant may be watched, and accumulations of dust, that impede the flow of the gas discovered.

Usually all the gauges are fixed on a single gauge-board and in plain view of the attendant. They consist of graduated U-shaped glass tubes of considerable length, and filled with a colored liquid. By reading the difference of the two surfaces of the liquid in both branches of the tube the depression is ascertained at once. If two neighboring gauges show a material difference in their readings, it may be suspected that one of the ducts located between them is clogged by dust, and must be cleaned. Of course the reading of the gauges calls for some skill and experience, as the liquid moves up and down at each suction stroke of the engine.

The Suction Gas Motor.

The suction gas motor proper does not differ materially from the Dowson gas engine; in fact, a motor may change from one system of gas producer to the other

without any difficulty. On account of the resistance offered to the gas on its passage through the producer plant, the power of the motor is somewhat reduced. Compared to an illuminating gas engine of equal size, the loss of power is about 20 per cent. In order to increase the output of power the compression has been raised to rather extraordinary figures. As the gas is of only low heating value, this may be done safely without inducing pre-ignitions. The compression varies in the different makes of motors between 150 and 230 pounds per square inch (absolute). In isolated cases much higher pressures are used, which, of course, are allowable only if the gas is carefully cooled before entering the engine. As in most large engines the throttling principle of governing is applied at present, by which means the size of the charge is varied without changing its composition, the high pressures exist only at full load, while at partial loads a corresponding reduction in pressure occurs.

No definite opinion has been formed yet as to which method of governing is

preferable. Doubtlessly the hit-and-miss method is apt to produce the greatest economy in the suction gas engine, just as well as in motors for another fuel. As with this mode of regulation the formation of each charge goes on under exactly predetermined and most favorable conditions, which are not changed by the number of impulses occurring during the unit of time, it is easy enough to adjust the engine properly and obtain good results.

The throttling method, though theoretically more perfect, offers many practical difficulties. Even the best governed can not keep the throttle entirely steady at partial load, and there will always be explosions of various strength in more or less irregular succession. As only the few impulses resulting from full charges approach in quality the impulses regularly obtained with the hit-and-miss method, the economic superiority of the latter is obvious. Nevertheless, the constructive simplicity of throttle regulation must be acknowledged, and this is one of the strongest points in favor of it, especially in large engines.

Upon the action of the generator plant the method of governing seems not to exert any marked influence.

As the generation of the gas depends upon the suction of the motor, it may be supposed that, with the hit-and-miss method, leaving the strength of the suction strokes entirely unchanged at any load, a uniform quality of gas is secured. The occasional intervals of time between the suction strokes, caused by the action of the governor and being only fractions of seconds, can not do any harm.

With the throttling method, however, the force of the suction, and incidentally the velocity of the air and gas, vary frequently, especially at partial load. Naturally these conditions are unfavorable for the uniformity of the gas, and they can only be bettered by good mixing devices at the motor, and by frequent careful adjustment of the gas and air supply.

For its perfect combustion in the motor the gas requires 1.25 times its volume of air. In newly designed engines the areas of the gas and air ports should consequently bear this ratio. If, however, an illum-

inating gas engine is to be adapted to suction gas, the gas passages must be considerably widened. The average speed of the gas should be about 82 feet per second, or even less, if possible.

The starting of a suction gas plant calls for a considerable number of manipulations that must be performed skillfully at the proper time and in due succession. Mistakes may delay the starting of the motor, or even render it impossible. Wrong operations with the valves may cause several dangerous incidents. Various methods are in use to overcome these difficulties.

Sometimes the engine is provided with a special gasoline atomizer, and the motor may be started easily enough with this volatile liquid. If the generator has been prepared previously, and everything else is in good order, after a few minutes of running on gasoline the gas may be admitted to the motor. This procedure is rather dangerous for the engine as the gasoline is liable to cause terrific explosions on account of the high compression, as soon as the motor becomes warm, unless pro-

visions are made to reduce the compression to a safe point. The easiest way to do this is to allow part of the charge to escape at the beginning of the compression stroke by keeping the exhaust valve open. An arrangement similar and in addition to the customary starting cam will suffice for this purpose. All these devices have the common drawback that the richest part of the charge escapes uselessly. For a few starting revolutions this is of no importance. As in a suction gas motor it might be necessary to work on gasoline for perhaps half an hour or longer, the loss of fuel would be considerable. The author would suggest the use of a small piston-controlled release port in the cylinder-wall, the outlet of which may be closed by a cock if it is desired to apply the high compression. This release port allows only the escape of the comparatively thin mixture near the bottom of the piston, and even this may be saved if the cock is connected by a pipe to the inlet-valve casing of the motor. The rich mixture in the compression chamber is preserved, and the engine will work with

full power and economically on gasoline also.

Another good plan, and one that is often practiced, if circumstances permit, is to start the motor with illuminating gas. This method offers no dangers whatever. In this case work may be taken up immediately with the engine and the generator may be prepared to resume its functions, and, after a while, is ready to feed the motor.

How a suction gas plant is to be handled, the reader will best learn from an extract of the directions which are furnished by a prominent firm with their plants. The booklet begins with a short explanation of the mode of operation, which has been fully described before, and consequently need not be repeated here. Next come some remarks of general character, as follows:

On account of the suction a depression prevails in all the apparatuses and pipes, and in case of a leak, or if a valve is opened during operation, no gas can escape, but air enters. Thereby the gas is diluted and the power of the motor reduced. If

large amounts of air enter, an explosive mixture is formed and danger is imminent. Consequently it is of the utmost importance to keep all pipes, valves and apparatuses in perfectly gas tight condition.

In order to test the joints, which should not only be done just before starting the plant for the first time, but also regularly at certain intervals, air pressure should be applied to the system by means of the ventilator (13). Investigation with a lighted candle will reveal leaks without fail, as the air blowing out causes the flame to waver.

Incorrect positions of valves, or lack of water in the siphons, may also permit the ingress of air. In order to avoid this the directions must be followed closely.

The generator room must always be well ventilated. The coal should be sieved, and grit of less than 1/8-inch thickness thrown out.

I. How to Start the Generator after Erection or after a General Cleaning.

First, inspect the whole plant carefully and get the motor ready. Take care that the siphons (30) are filled, also the vaporizer and the pan in the ash-pit. Close the scrubber valve (34) and the steam valve (25) and open the ventilator valve (14), also the fire door (11) and the ash door (12). Now open the valve (20) in the flue, and kindle a good wood fire in the generator just as in a common stove. When the wood is burning put a few coals on top, and after awhile fill up the generator gradually. Next, close the charging funnel, also the doors, and work the ventilator vigorously. In a few minutes the fire will burn brightly. Continue to blow until the gas may be lighted at the test cock (26) and burns steadily. Now shut the ventilator valve, open the ash door, and loosen the slags and ashes on the grate with a poker. Then rake the refuse out at the fire door without throwing out any good coals, however. Also clean out the slags near the fire door. By these operations the fire may have died down. Af-

ter closing the doors it will be necessary to blow again for a short time till the gas burns properly at the test cock.

When the plant is put in operation for the first time, or, if for some other reason the system contains no gas at all, the gas must be driven through the same with the aid of the ventilator. Open the scrubber valve and work the ventilator till all the air has been displaced and gas appears at the test cock (33) near the engine. If the gas escaping here burns properly, the motor may be started.

II. How to Start the Motor.

Close the ventilator valve and start the motor immediately. All the preparations should be made in advance in order to avoid loss of time, as the gas might deteriorate in the meanwhile.

During the operation of the engine the flow of water in the vaporizer must be so adjusted that the overflow keeps the pan in the ash pit well filled.

III. How to Charge the Generator.

The coals should not be allowed to burn

down into the heating space. If a recharging becomes necessary while the engine is running, this must be done quickly and the funnel must be closed at once.

The funnel should never be left uncovered for any considerable time unless the flue valve (20) is opened.

IV. How to Stop.

Stop the motor as directed. Open the vent (33) near the motor, also the charging funnel. Shut the vent after a minute or two, and close the scrubber valve. This must not be omitted, as thereby combustible gas is retained for the next starting. Shut off the several water supplies and the steam valve (25), and adjust the air inlet (18) so that the generator continues to burn slowly. Of course the valve (20) in the flue must be opened during the stop.

V. How to Start after Short Stops.

If the coal in the generator is burning yet, proceed as follows: Open the doors of the generator and remove the slags as described under I. Close the doors again,

open the ventilator cock and blow air through the generator till the gas burns well at the test cock (26). Continue as directed under I and II.

VI. How to Clean the Grate.

The ashes must be removed from the grate at intervals of some hours, depending on the quality of the fuel. This can be done while the generator is in operation, but must be done quickly. If much refuse clings to the walls of the generator and cannot be reached through the doors, the fire must be drawn out, and after the generator is entirely emptied the dross and slag is knocked off with some suitable tool. If a thorough cleaning is intended do not empty the generator on Saturday night to leave it to cool out during Sunday, as the sudden exposure of the hot generator lining to the cold air may ruin it. Clean the generator on Monday morning and start again immediately.

VII. How to Care for the Scrubber.

The pieces of coke that serve to fill the scrubber should be of such size that they

do not drop through the grate. Sufficient water must be admitted at the top for the cooling of the gas. The scrubber should be cleaned at intervals of from 9 to 12 months in accordance with the intensity of its work.

A cleaning of the scrubber can be undertaken only when the generator is out of operation. Close the scrubber valve and remove the covers of the man-holes. Allow the scrubber to stand open for several hours till all the gas has escaped. Next pull out the coke through the lower man-hole with an iron hook. After the interior of the scrubber is well cleansed it is filled with fresh coke. Both openings are now covered again. Injured packings must be replaced.

All these operations must be performed in daylight only. No fire or light, and no smoking should be permitted. At least two attendants should be present, and the doors and windows left open in order to avoid gas poisoning.

VIII. How to Clean the Pipes.

The piping should be looked over and cleaned at least once a month. As most impurities settle in the elbows, especially near the scrubber, these places require special attention. For cleaning, the pipes should be disconnected.

The Properties of Suction Gas.

The properties of suction gas, especially those that are of value to the designer, may be mentioned here, shortly. Suction gas may be produced from any hard coal, coke, or anthracite, if the fuel leaves no considerable amount of incombustible residues, and if the gas itself is free from tarry and other condensible admixtures. In the commercial suction gas plants anthracite or coke is generally utilized, though occasionally special generators working on peat, the residue of city sewage, and other combustible matters, are built. Suction gas is a semi-water gas; it burns with a faint, blue flame. Its smell is less penetrating than the odor of illuminating gas. On account of the monoxide

of carbon contained therein, it is very poisonous and may produce asphyxia.

One pound of coke or anthracite furnishes between 64 and 77 cubic feet of gas. The heating value may vary from 135 to 146 B. T. U. per cubic foot. One cubic foot of gas requires .95 to 1.1 times its volume of air for its perfect combustion, theoretically, while practical experience calls for at least 1.25 times the volume of the gas. A cubic foot of gas weighs between .065 to .0748 pounds. If the density of the atmospheric air is considered as the unity, the density of the gas is .8 to 1.1.

The chemical composition varies considerably, not only with various makes of generators, with different fuels or with other variations, but even under apparently unchanged conditions, and is especially influenced by the height of the column of coal within the generator, by the force of the suction and by the amount of water vaporized and drawn through the fuel.

According to the average of a great number of careful analyses made by Prof.

Meyer, a gas obtained from coke of 13239 B. T. U. per pound contained of

Hydrogen H	70	parts.
Monoxide of Carbon CO	276	"
Carbonic acid CO_2	48	"
Methane or marsh gas CH_4	20	"
Nitrogen N	586	"
(By volume) in 1000		"

One cubic foot of this gas weighs .0748 pounds. Its density as compared to air (=1) is .93. For its perfect combustion, at least an equal amount of air is necessary. Containing only little hydrogen, its specific gravity is great and its heating value comparatively small, 135 B. T. U. per cubic foot.

Similar tests of a gas produced from anthracite of 14,256 B. T. U., made by the same experimenter, gave the following results:

1,000 parts of the gas by volume contained of

Hydrogen H	242	parts.
Monoxide of carbon CO.....	166	"
Carbonic acid CO_2	113	"
Methane CH_4	20	"
Nitrogen N	459	"
	1000	"

This gas weighs .0654 pounds per cubic foot. Its density is .8, its heating value is 146 B. T. U. per cubic foot, while the smallest amount of air required for its perfect combustion is 1.15 times its volume.

Of the various constituents of suction gas only hydrogen, marsh gas and carbon monoxide are useful for the production of heat and power, while the others, carbonic acid and nitrogen, produce no heating value at all and are entirely useless. They serve only to dilute the gas and decrease its heating power per unit.

The actual heating values of the first named gases, which may be utilized in the motor are, by weight, as follows:

Hydrogen 52,000	B. T. U.	per lb.
Carbon monoxide, 4,400	"	"
Marsh gas 25,500	"	"

They are by volume as follows:

Hydrogen .. ....290 B.T.U. per cu. ft.
Carbon monoxide, 354 " "
Marsh gas .. ...976 " "

measured at O° C. and 32 inches mercury pressure.

The marsh gas, though of high heating value, does not count much, as too little of it is present. Thus the hydrogen and the carbon monoxide must be considered the most powerful constituents of suction gas.

Looking at both preceding analyses it will be noted that the indifferent (that is, useless) gases CO_2 and N occupy the greatest part of the product. CO_2 is the result of perfect combustion, consequently its production consumes fuel for which no returns come in. It is caused by a surplus of oxygen, or air. The nitrogen is of course no product of the generator, it is introduced as the indifferent element of the air which is drawn through the fuel. It is easily perceived that in both cases the excess of air is responsible for the existence of the useless parts, and

the recognition of this fact may possibly lead to improvements. At present the highest efficiency obtainable in the suction gas generator, that is the ratio of the heat value contained in the fuel and the heat value recovered from the gas, is between .75 and .83. The deficiency of 17 to 25% is caused by imperfect gasification, direct losses of gas and by radiation. If, however, there is taken into consideration the amount of fuel which is consumed during stops and for starting, the total efficiency of the generator will be about .60 to .70 of the original heating value of the fuel.

The gas leaves the generator at a temperature of from 500 to 750° C. varying with the amount of fuel and with the time between charging. A considerable amount of heat is thus carried away, which must be destroyed at extra expense in the cooler, unless it is turned to some useful purpose. There are several ways in which this may be done and a saving effected.

First: The heat in the gas should not only convert the water into steam but also superheat the steam as much as possible.

Very hot and dry steam does not withdraw heat from the bed of fuel.

Second: The heat in the gas might be used to pre-heat the air entering the generator. As has been explained previously the amount of air should be reduced to the utmost in order to decrease the volume of the indifferent gases. If the air is thoroughly heated, less fuel is consumed in order to raise its temperature to the average of the gas.

Third: The hot gas might be led through or around the fuel contained in the heating space of the generator and thus give up part of its heat to raise the temperature of the fuel.

The heat contained in the exhaust gases might also be turned to account in the manner indicated and would thus support the action of the hot gas, if necessary or desired.

By the careful utilization of the heat the functions of the scrubber would be reduced very nearly to a filtering action only, the gas being cooled before it enters this apparatus. The generator as well as all the other ducts containing hot gases

should be carefully protected against losses of heat by radiation.

It is to be expected that during the course of evolution the suction gas producer will be continually improved upon till the theoretical efficiency is very nearly reached.

European Conditions and Tests.

With reference to European conditions the suction gas motor is at present the most economical artificial source of power, as far as the consumption of fuel is concerned. Engines from 4 H. P. up to several hundred H. P. are in operation throughout the industrial countries of Europe in considerable numbers, in spite of the novelty of the system, and the demand is greater than ever. Judging from the testimonials given to the manufacturers and published freely in the papers and catalogues, the consumption of the suction gas plant, expressed in the money value of the fuel, averages from $0.0025 to $0.0075 per B. H. P. an hour. These figures vary according to the size of the plant and the price of the fuel

which is greatly influenced by the cost of transportation.

The statements of the manufacturers are fully borne out by the results of many tests made of engines of various sizes, with different fuels and under the conditions of regular works. Only of a few interesting tests, short extracts shall be given here.

1. A 30 H. P. built by the motor works of Moritz Hille at Dresden-Loebtau was subjected to a very careful test. It was of the horizontal four-cycle type. The bore of the cylinder was 11.8 in., the stroke 18.11 in. and the regular speed 200 r. p. m. The engine was provided with magneto electric ignition and governed on the hit and miss principle. Starting was effected by gasoline. For this purpose a small inlet valve and a gasoline atomizer were fixed at the cylinder head. In order to reduce the compression to the figure allowable for gasoline, the exhaust valve is kept open during part of the compression stroke. A little cam on the gear shaft is shifted to strike the roller of the exhaust valve lever at the

proper time. In this way the engine may work on gasoline safely without being exposed to the dangerous strains otherwise resulting from excessive compression. After running some time the gas cock is opened and the gasoline supply shut off for a trial, and if the engine continues to ignite regularly the gas is in good condition and the starting valve is drawn upon its seat tightly by a milled nut on its stem.

Indicator cards taken during the test showed the extremely high compression of 326 pounds, absolute, while the explosion rose to 468 pounds, absolute, a value which in itself is pretty high, but appears rather low in comparison to the compression. The mean indicated pressure of the diagram was 66.45 pounds above atmosphere. During the test the engine developed 31.68 B. H. P. constantly, and there occurred 7.2 misses per minute on an average. The I. H. P. computed from the diagrams was 39.44, and the efficiency of the motor 31.68: 39.44=.80.

The cooling water entered the jacket of the motor at 10 degrees C. and left at

46.5 degrees C. The amount passing the jacket in one hour was 1893.5 pounds (227.7 gallons), the heat absorbed by the jacket water, 124,713 B. T. U.

The exhaust gases contained 101,018 B. T. U., measured by the rise of temperature and the amount of the water used to cool them.

The cooling water entered the scrubber at 10° C. and left it at 25.3° C. The hourly passage amounted to 476.67 pounds (57.33 gallons), resulting in a loss of 13,160 B. T. U. per hour.

The test consisted of three runs of three hours each; during this time 257.4 pounds of anthracite were consumed.

The analysis of the fuel showed the following comparison:

100 parts of the fuel contained

2.4950	parts	of	humidity
7.3475	"	"	ashes
2.9275	"	"	impurities
2.6725	"	"	hydrogen H
84.5575	"	"	pure carbon C
100.0000	parts.		

The heating value of one pound of this fuel was 13,714 B. T. U.

The generator vaporized and decomposed 23.95 pounds (2.9 gallons) of water of 10° C. per hour. This process consumed 165,366 B. T. U.

Each pound of pure carbon is consequently accompanied by .182 pounds of various other stuffs, and 1.182 pounds of the fuel contain 1 pound of carbon. The heating value for one pound of carbon is 1.182×the heating value of the fuel, =1.182×13,714=16,218 B. T. U.

The gas obtained from 1 pound of carbon is by computation found to contain 13,841 B. T. U.

As the total amount of fuel consumed during nine hours was 257.4 pounds, for each hour 28.6 pounds were required in which 28.6÷1.182=24.18 pounds of carbon are contained. The heating value of the gas produced therefrom is 24.18 ×13.841=334.675 B. T. U. Of this total output of heat energy the engine transferred in indicated work

$$\frac{39\,44 \times 33000 \times 60}{778} = 100{,}374 \text{ B. T. U.}$$

Consequently the heat balance is as follows:

	B. T. U.
Heat utilized in engine	100,374
Heat absorbed in cooling water	124,713
Heat escaping with exhaust	101,018
The rest for radiation	8,570
	334,675

Expressed in percents of the total heat energy, the heat utilized in the engine is 29.9%, the cooling water absorbs 37.2%, the exhaust carries off 30.1%, and the rest of 2.8% are lost by radiation.

In order to measure the fuel consumption the anthracite was divided in lots of 90 pounds. After removing the ashes and thereby causing the fuel to settle, the distance from the top of same to a mark on top of the generator was measured by introducing an iron bar through one of the peep holes in the top plate of the generator. Next the latter was charged with the amount of 90 pounds of anthracite and the time measured which elapsed till the same mark was reached again. On account of the formation of extremely

little slag that might influence the result, the experimenter deemed this method to be sufficiently exact.

As 28.6 pounds were consumed per hour each H. P. required $28.6 \div 31.68 = .902$ pounds of anthracite.

The price of the fuel was $66.10 for a carload of 22,000 pounds, that is .3 cent per pound, and $.902 \times .3 = .27$ cent is the cost of fuel for one B. H. P. hour.

2. A suction gas plant furnished by the Gasmotoren-Fabrik Deutz was tested in a shop at Nuremberg. The report of the two experts making the test was as follows:

The fire in the generator was kindled with wood at 8.50 A. M. The motor was started immediately with illuminating gas and drove the ventilator that served to blow air into the generator. After the latter had been partly charged with anthracite, the motor began to work on suction gas at 9.20. At 10.34 the generator was filled up to the top and at 10.37 A. M. the brake test was started. The run lasted exactly five hours, during which the motor developed 23.4 H. P. constantly, measured by a prony brake. At 12.15

P. M. 30.8 pounds, and at 2 P. M. 35.3 pounds of anthracite were put into the generator. At the end of the test, at 3.37 P. M. the ashes and slag were removed and 48.84 pounds of fuel were required to fill the generator to the top. Consequently the amount of the fuel was 30.8+35.4+48.84=114.94 pounds of anthracite.

The number of revolutions had been counted continuously and was exactly 200 per minute.

The consumption of fuel per B. H. P. hour was 114.94 ÷ (5×23.4)=.982 pounds. The price of the anthracite was $68.51 for the carload of 22,000 pounds, that is .31 cent per pound. The cost for the A. H. P. hour is consequently .982×.31=.3 cent.

The anthracite was of the mines at Langenbrahm. Its heating value was 14,979 B. T. U. per pound, it contained only .49% of humidity and 2.71% of ashes. The fuel was very well suited for its purpose as it produced very little dross. The gas was so clean that after the test the inlet valve of the motor showed only a scarcely preceptible coat of soot.

3. A 40 H. P. suction gas motor built by the Schmitz Motor Works, at Cologne-Ehrenfeld, was tested on the stand of that firm by an expert. The motor was of the single cylinder Otto type. It was provided with a throttling governor and electric ignition. Its main dimensions were:

Diameter of cylinder ....13.77 ins.
Stroke .....21.25 "
No. of revolutions ....200 per min.

The tests were made with a water-cooled Prony brake. The motor developed 49 H. P. maximum at 194 r. p. m. The consumption of coal during a run of three hours, under an average load of 46.6 H. P., was 124.3 pounds, or 88 pounds per B. H. P. hour.

The analysis of the coal from the Kohlscheid mines showed the composition of the fuel as follows:

Carbon	88.5	percent
Volatile parts	6.6	"
Ashes	3.7	"
Humidity	1.2	"
	100.0	

The heating value of this coal was 14,-

626 B. T. U. per pound, or 15,380 B. T. U. per pound of the pure fuel. The consumption of water in the generator was found to be .105 gallons per H. P. per hour, including occasional losses by spilling and the like.

The indicator cards showed a maximum compression of 150 pounds absolute, and a maximum explosion pressure of 340 pounds absolute.

These pressures exist only at full load; at partial load they are even less. Considering these comparatively low pressures, the results obtained are very favorable.

General Remarks.

It may be stated safely that the cost of fuel in the suction gas plant is about 50 or 60 per cent less than in a steam plant, while electric power is at least 10 to 15 times more expensive. Of course the data of the foregoing tests are very favorable as obtained under carefully equalized conditions. There is no doubt that a plant under the care of a man of average intelligence may consume considerably

more fuel and usually will do so. The amounts necessary for starting and for carrying the generator over stops must also be taken into account, which have been omitted in the tests. But even if the figures of the tests were doubled by carelessness or ignorance, the suction gas plant would range among the cheapest power producers. Though often enough, as is usual in gas engine practice, the little amount of attendance, labor and care which the suction gas plant requires is eulogized, the directions given out by the makers prove sufficiently the fallacy of this claim. The author does not believe that in countries which abound in cheap liquid and gaseous fuels the suction gas motor will supersede the handy and ever ready engines running on those fuels. In the European countries, however, where fuels of any description are expensive the economy of the motor generally counts more than comfort, and the discomfort connected with the suction gas plant is willingly taken into the bargain.

The system will make its way without fail, though probably the favor of the

public, which had at first been won by all the arts of skillful and persistent advertising rather than by the real merits of the matter, will abate somewhat, and the demand will be based upon the careful investigation of the properties, good as well as bad, of the suction gas system. Only by the perfect recognition of all its qualities may the field for its application be sharply circumscribed.

It may be mentioned here that for intermittent work, or if the motor is used only for a short time once in a while, a plant of this description is not to be recommended, as the trouble in restarting would be prohibitive, and on the other hand it would not be economical at all to sustain a fire in the generator continuously. If gas is required for other industrial purposes, as for smelting, soldering, annealing and the like, or for heating the localities, a suction gas plant cannot be utilized for these purposes, as all the gas produced must be fed to the motor, and it would be difficult to tap the generator. A case of this kind would call for a Dowson gas plant.

There are at present in operation gas producers adapted to work in both fashions, either by pressure or by depression. There are also types of producers, partly in the experimental stage, or a very few specimens in actual operation, that gasify other kinds of combustible matter which hitherto have not been thought of for the production of power.

It is surprising to see how the seemingly short step from the Dowson gas plant to the suction gas generator has been the cause for the development of a number of important devices that may prove to be of the utmost economic value in power production. Some of these rather abnormal gas producers are of such high technical interest and will contribute probably so much towards the widening of the field of the gas engine that the reader will appreciate some information concerning them.

While generally anthracite and coke had been considered the only proper fuels for producer plants, experiments have been going on continually to utilize other less expensive fuels also. It was found

that nearly every combustible substance could be used to generate a gas adapted for motor use, but seemingly insurmountable difficulties were encountered as soon as the gasifying process yielded considerable amounts of tarry residues. The attendance necessary in this case and the frequent cleaning required made continuous work rather impossible. Only after it had been learned how to change the tarry admixtures into permanent gases was a solid basis for the construction of practical producers found. Illuminating gas practice had solved the problem long ago by highly superheating the gas, and the same method is used now in the gas producers for bituminous substances.

A Peat or Turf Generator.

A generator for the gasification of peat or turf, as built by Koerting Bros., of Hanover, Germany, is illustrated in Fig. 4. As the fuel, even if dried superficially, contains a great percentage of humidity, it is not necessary to add water-vapors to the charge of the generator, and the vaporizer proper becomes superfluous.

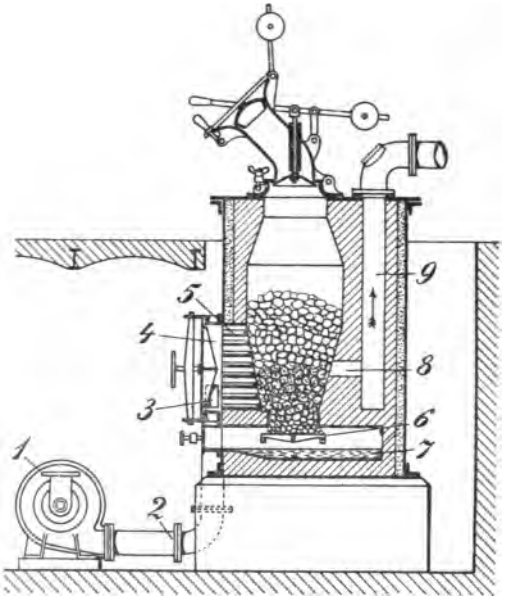

FIG. 4.

The air required to sustain combustion is supplied by a rotary fan (1) driven by the motor. It is delivered by a pipe (2) and opening (3) into the chamber (4) formed by the frame of the fire-door and its cover. A number of cast-iron plates (5) support the fuel and divide the air in several streams, at the same time heating it considerably. Below the grate (6) a flat water-pan (7) is placed. The level of water is kept constant by a siphon-like contrivance. The heat of the combustion causes a dry distillation in the upper regions of the fuel. The gases are not drawn off at the top of the generator, as has been described previously, but they are compelled to pass the white hot layers of fuel near the bottom of the fire space that have already yielded their gas. By the contact with these hot parts the tarry admixtures are superheated and decomposed, and a clean, permanent gas is the result. Ultimately the gas leaves the generator by the ducts (8) and (9), as indicated by the arrows, and, after passing the customary cooling and purifying devices, is led to the motor.

The firm published a report about one of their suction gas plants which used for fuel peat pressed in brick shape. The generator fed a gas engine of 100 H. P., combined with a dynamo. The heating value of the fuel was 8,754 B. T. U per pound. It contained—

Carbon	48.32	parts
Hydrogen	3.35	"
Oxygen and nitrogen	26.54	"
Sulphur	1.09	"
Ashes	5.00	"
Humidity	15.70	"
	in 100.00	parts

During a ten hours' brake test the engine consumed 1.43 pounds of this fuel per actual H. P. per hour. The price of the compressed peat was $1.66 per long ton at the mine.

As the fuel is of light weight and very bulky for its heating value, it can not bear high transportation expenses, and must be consumed right at the place where it is found. On the other hand, these same properties call for a large and costly plant. Consequently, the economy of the same de-

pends in a great measure upon various conditions that must be weighed carefully, and which, of course, would apply in the same manner to a steam engine plant. The superior efficiency of the gas engine, as far as the utilization of heat is concerned, may often, however, warrant the installation of a peat-gas producer even in cases where another source of power would be ruinous from a financial standpoint.

It will be noted that the plant just described does not depend solely upon the suction of the motor, as the fan rotating at practically constant speed forces a fixed volume of air into and through the generator, and, by setting up a certain pressure within the system, causes the gas to flow into the motor as soon as the inlet valve is opened. The process of gasification will go on more uniformly, the motor will receive a fuller charge, and, consequently, develop more power. This gain in power surpasses the amount necessary for the running of the fan considerably, and improves the efficiency of the

plant. For this reason the little complication is justifiable.

In medium and large size producer plants the addition of the fan running uninterruptedly and relieving the motor of the resistance of the charging stroke seems to be the rule at present. The fan is driven by a belt from a pulley on the motor shaft; sometimes a little electric motor is provided for this purpose.

Of course the character of a "suction" gas plant is less defined in this case; in fact, the boundary line between the various types of producers is pretty hard to draw.

In the devices which, at present, for lack of a better name, are called suction gas plants, the absence of the boiler must be considered the principal and deciding feature.

Gas from Sewage.

A special generator for a very peculiar fuel has been designed and put in successful operation recently by the Gasmotorenfabrik Deutz. This device utilizes the solid matter contained in the city sewage

and extracted therefrom by an ingenious process. The problem solved by the construction of this generator, in connection with a system of obtaining the fuel, is of such great importance that a few explanatory words may be allowed.

The difficulties connected with the disposal of the immense amounts of waste matter accumulating wherever considerable numbers of people are crowded together in towns and cities are generally known. They are growing continually, not only with the increase of population, but also with the higher ideas of the inhabitants as to cleanliness and good sanitary conditions. To remove the more solid refuse, as garbage and rubbish, is not so very difficult and important as to render harmless the big stream of offensive liquids comprising the city sewage. From times immemorial these liquids have been allowed to flow into the natural watercourses, until modern science has recognized this contamination of the water supply as the hitherto mysterious cause of many deadly epidemics.

Naturally, many devices to overcome

these dangerous conditions have been tried, generally with but little success and mostly at great expense, and thus the financial question has always been the main impediment to progress. Therefore, a method which does not only purify the sewage, but also renders the by-products of the process available in an extensive measure, would be very desirable. The system of Messrs. Rothe & Degener seems to fill all reasonable expectations. It not only separates the solid matter entirely from the liquid, but also adapts the former to be sold as a fertilizer or gas-yielding fuel, thereby covering all the expenses of the process, and even bringing a good profit.

The procedure is as follows:

The sewage is collected in large tanks. A thin mixture of water and powdered brown coal or peat is added to the contents of the tanks, and thoroughly mixed therewith. The particles of humus-like substance, being practically imperfectly carbonized organic matter, float in the water and combine with the stuffs of similar character; that is, of animal and veg-

etable origin. After a certain time sufficient amounts of dissolved salts of iron, aluminum and magnesia are added to the tankage, that cause the rapid settling of the suspended solids. The clear water is drained, the mud removed and dried. It may either be used in its organic shape or pressed in bricks for storage. The inventors claim that the finely divided peat absorbs the putrefactive matter, and the settling of these stuffs, which goes on under the influence of gravity, is accelerated by the addition of the salts.

The method is in operation in a number of cities, and gives good results.

If the products of the process are used as a gas-engine fuel, a little calculation, based upon the data obtained hitherto, will show how favorable the financial outlook is for a city power-plant.

For a town of 50,000 inhabitants the sewage plant must dispose of about 141,200 cubic feet of liquids that yield some 26,000 pounds of combustible residues. As a medium-sized motor will develop one B. H. P. per hour on 4.4 pounds of this fuel, the daily output, when transferred

into gas, would develop 6,000 H. P. for one hour. One H. P. hour of motor-work equals .736 × .90 = .66 kilowatt hours; the daily output would be 6000 × .66 = 3960 kilowatt hours, and the total amount of electric energy for one year would be 365 × 3960 = 1,445,400 kilowatt hours.

Suposing, now, that some 15 percent of this amount were necessary to cover the running expenses of the plant, the rest of 1,230,000 kilowatt hours annually may be sold for the benefit of the town's treasury.

Thus the sewage purifying and utilizing method of Rothe & Degener, in connection with the suction gas motor, may be considered an excellent solution of this difficult question in modern town administration, both as far as public health and political economy are concerned.

The Sewage Gas Producer.

Similar to the peat gas generator of Koerting Bros., the generator of the Gasmotorenfabrik Deutz is provided with a rotary fan driven with a little electric motor. The air is blown below the

grate of the generator; an adjustable vent in the air supply pipe serves to regulate the amount entering the fuel. The generator proper shows no marked difference compared with the type for coal. Its interior dimensions are rather ample, in order to accommodate the poor and bulky fuel. A special vaporizer is not necessary. The water contained in the fuel and the steam rising from the water-pan in the ash pit are fully sufficient for the formation of the gas. The latter leaves the generator at the top and enters the upper part of a vertical cast-iron cylinder, which acts as a dust collector. Next the gas is led to a box partly filled with water. The inlet pipe is funnel-shaped, and its widened end dips into the water which must be passed by the bubbles of gas and retains many solid impurities. On the other hand, this washer serves as a kind of non-return valve, which prevents the gas from traveling back into the generator if the blower stops for some reason. After passing a scrubber the gas is collected in a little gas holder of sufficient capacity to

carry the engine over occasional fluctuations in the output of the generator, as caused by recharging or cleaning. In both the inlet and outlet pipes of the gas holder water traps are provided. Near the engine a large gas vessel is placed, which receives about twenty charges of the power-cylinder.

The gas obtained from the residues of sewage by this producer plant has a heating value varying from 95 to 112 B. T. U. per cubic foot.

Portable and Traction Plants.

It is self-evident that the suction gas plant may be adapted to all kinds of stationary purposes that are at all fit for gas engine work. Whether this system of power production will be available for traction or locomotion practice is a question which probably must be answered in the negative.

The weight of an average gas producer plant, as presently built, for say 50 H. P., which is not extraordinary for a heavy traction engine, is some 5,000 pounds. Supposing, now, that by the most careful

design and the use of highest grade materials only the weight could be reduced to about one-half of this figure, it would yet be excessive if compared to a motor plant for liquid fuel. It must be remembered that the generator consumes a considerable amount of water which, besides the cooling water for the motor and scrubber and the coal, would add another big load to the vehicle.

There is a slight possibility that a suction gas plant of sufficient capacity may be carried on a locomotive, as in this case the weight is necessary to secure sufficient adhesion to the rails.

Marine Plants.

The suction plant has, however, made a successful attempt to conquer one branch of locomotion, which is not hampered by lack of water and considerations of weight, namely, the propulsion of vessels.

The Gasmotorenfabrik Deutz seems to have taken the first steps in this direction. This firm provided a number of large vessels with suction gas motors. In flat canal boats the place near the stern easily ac-

commodates the engine plant. The motor is of the standard horizontal type, and, with its cylinder parallel to the center line of the boat, placed as far abaft as possible. Somewhat more forward, to one side of the motor, stands the generator. The scrubber is placed on the opposite side, and the gas vessel is fastened to the deck between the two. The whole plant occupies a very small space, and is separated from the other parts of the boats by a solid bulkhead. A small pump driven by the motor furnishes the water for the generator and the cooler. A gasoline reservoir for starting is fixed to the deck. The flue of the generator passes the deck through a bushing. Its weight is counterbalanced and it may be moved up and down easily. This is a peculiarity of the Deutz producer. After the lid of the filling funnel is tilted out of the way, the flue is pulled down upon the opening of the funnel, forming the direct connection from the interior of the generator to the open air, and carrying away the smoke. The arrangement of the flue (19), as shown in Figs. 1 and 2, seems to be preferable,

being much cheaper in construction and handier also, as the filling funnel is left entirely undisturbed. What the reasons are for the rather complicated design of this unimportant part of the Deutz generator, the author has been unable to ascertain.

The mode of power transmission between the motor and the propeller, though irrelevant here, deserves a few words of explanation.

In order to meet the various exigencies of canal-boat service, the propeller may be raised or lowered, as required. For this purpose the end bearing of the propeller shaft is carried in a slide guided between two parallel and vertical bars at the stern. By means of a threaded spindle and hand-wheel the location of the propeller may be adjusted. The other end of the shaft enters a ball-shaped box, provided with two hollow pivots. A suitable recess in the shell of the boat receives the box, and the pivots penetrate the sides of the recess through stuffing boxes. One of the pivots serves for the entrance of a short shaft carrying a pul-

ley outside and a bevel gear meshing with another on the propeller shaft, within the round box. The shaft is driven by a belt from the friction clutch pulley on the motor shaft. Through the other pivot enters a bar for the operation of the reversible propeller, which is controlled by a hand wheel on deck.

In deep-water vessels the propeller shaft is not made movable. Thereby the driving mechanism is much simplified, as the propeller-shaft may be coupled directly with the motor shaft. In every case the various operating handles are placed close to the helm, enabling one man to control the boat.

As compared to a steam engine, the gas producer plant offers great advantages in boat propulsion. In an average boat of 275 tons capacity the total expenses, including fuel, amortisation, repairs, etc., per ton and mile are calculated at from .024 to .03 cents. Outside of this economy, the suction gas plant effects a considerable saving in valuable space, on account of the small size of the machinery and the smaller space required for the

coal. Thereby the freight-carrying capacity of the motor-propelled vessel is notably increased, as compared with a steam boat of same size.

Advantages of Suction Gas.

With the suction gas plant continuous service is easily secured, as all its apparatuses, containing no pressure, but rather a depression, may be opened and cleaned during regular work. If one or the other cleaning-hole is uncovered for a short time only, the deterioration of the gas is so slight that the engine will show no notable difference in its action. The same is true of those plants that depend upon a mechanically operated fan for their air and vapor supply. By stopping the fan the pressure within the system disappears, and the plant continues to work on the suction plan, which permits all the necessary cleaning operations.

In order to make a Dowson gas plant fit for uninterrupted service, costly reserve apparatuses must be provided. Generally, an extra boiler and generator must be added. Naturally the first cost of the

installation and the required space is thereby considerably increased.

Combined Dowson and Suction Gas Plants.

By a skillful combination of both competing systems of gas producers, many objections have been overcome. There are producer plants in operation which may work alternately in both ways. Regularly the plant is operated on the Dowson method; but at certain intervals, especially if a cleaning of the boiler becomes necessary, the suction method is applied simply by changing the position of a few handles. By this arrangement the number of reserve devices is reduced, while on the other hand a greater reliability of the whole plant is secured.

Plants of this description are generally built only on special order, and for specific conditions. They are, of course, more expensive than those built for common, all-around work. The latter type is thrown on the market in great numbers by very many manufacturers. It consists only of the devices necessary for the production of a fairly satisfactory gas, name-

ly, the generator, the vaporizer, the scrubber and the connecting pipes.

Prices and Weights.

The printed matter of most manufacturers shows a surprising likeness, so far as the prices and weights of these simple plants are concerned. The average figures are compiled in the following table:

H. P.	Price.	Weight.
4 to 8	$400 00	3300 lbs.
10 to 16	450 00	3700 "
20 to 25	525 00	4800 "
30 to 35	600 00	5300 "
40	650 00	7000 "
50	700 00	8000 "
60	800 00	8500 "
75	850 00	9000 "
100	900 00	10000 "

The purifier (VI, Fig. 2) and the regulator (IV, Fig. 2) are furnished on order only. The average prices of these devices are as follows:

Sawdust purifier for 4 to 8 H. P. $82, regulator $35; purifier for 10 to 16 H. P. $92, regulator $35; purifier for 20 to 25 H. P. $105, regulator $35; purifier for 30 to 35 H. P. $125, regulator $50; pu-

rifier for 40 H. P. $135, regulator $50; purifier for 50 H. P. $170, regulator $75; purifier for 60 H. P. $170, regulator $75; purifier for 75 H. P. $180, regulator $90; purifier for 100 H. P. $200, regulator $100.

These prices are for plants working on anthracite; if coke is to be used, the prices are raised about 10 percent. The motors proper cost about the same as illuminating gas engines of same size.

Some Suction Gas History.

A few words about the history of the suction gas producer may close this discussion.

In the early eighties of last century Mr. E. Dowson succeeded in constructing a gas producer which worked satisfactorily in connection with a Crossley engine of about 150 H. P. The advantages of this system of power production were soon appreciated, and Dowson gas plants made their way all over the world, supplying many thousands of horsepowers. Its success set at work many bright heads to find out improvements and to render the gas

plant more simple and better adapted to the needs of small power plants. These endeavors led to the invention of the suction gas producer. Who first ventured the seemingly short step between the two important systems of power production, and when this was done successfully, is not known exactly. At present several people claim, or are claimed, to be the original inventors. In Germany Julius Soehnlein, a mechanical engineer of Schierstein on the Rhine, designed and constructed in 1891 a gas producer which, according to the testimony of eye witnesses, worked satisfactorily in common with a two-cycle engine.

In France Bénier experimented on the same lines. In 1891 he put in operation his first suction gas plant. The producer contained all the elements of the modern plant; some of its details, for instance, the design of the combined vaporizer and grate (as explained previously in the chapter on the generator) are very ingeniously conceived. The motor was of 15 actual H. P. It worked on the two-cycle principle, and was provided with a charg-

ing pump which drew the gas from the generator. One of these plants was submitted to a careful test by Aimé Witz, the French expert. The results—a consumption of 1.57 pounds of anthracite, or 1.65 pounds of coke per B. H. P. per hour—were a surprise at that time, especially if the imperfect motor was taken in consideration.

In 1898 Bénier combined with Taylor in order to continue his experiments. The various devices were greatly improved upon, and soon an absolutely reliable, simple and economical plant could be offered to the public at a comparatively low price.

Since that time the progress in the development of this most modern type of gas producer has been immense, and nearly without precedent in the history of machinery.

Doubtless the profession will not be satisfied with the present success, gratifying as it be, but will continue to devise many more improvements, whereby the qualities of the suction gas producer are perfected and its field of application broadened.

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